Applying Context-Awareness to Service-Oriented Architecture

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Context-Aware and Ambient Applications, 2007

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Outline

1. **Motivation**

2. **Context Management**
   - A Proposed Layered Reference Architecture
   - Sensing
   - Context Data Representation in the Context Repository
   - Context Querying and Reasoning
   - Context Provider (Aggregation and Delivery)

3. **Selected Systems Applying Context-Awareness and Service-Oriented Architecture**
   - Service-Oriented Context-Aware Middleware (SOCAM)
   - Context-Sensitive Service Discovery System (CSDS)

Context-Aware Applications.

- Mobile Devices
  - Good computing power, memory, networking
  - User experience limited by interaction with small displays and keyboards
- Context-Awareness
  - Minimizes amount of interaction user ↔ device
  - Enables provision of situation-dependent services
  - ⇒ augmented reality

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Service-Oriented Architecture

- Recent paradigm in Software Engineering
- Services
  - Loosely coupled
  - Distributed
  - Fulfill specific functionality according to a service contract
  - Functionality implemented and deployed once only
- Create applications by composing services
- Typical roles
  - Client
  - Service repository
  - Service provider

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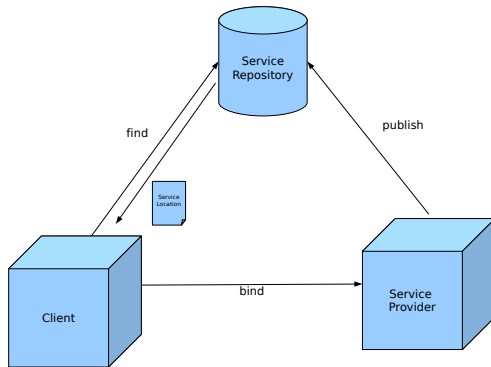
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Service-Oriented Architecture

Figure: Roles and interactions in an SOA

Context-Awareness and Service-Oriented Architecture

- Mutual influences between context-awareness and service-oriented architecture
- Context-aware applications
  - Context-aware middleware solutions based on SOA paradigm
  - Use composition to integrate partial contexts
- SOA
  - Context-aware service discovery
  - Context-aware service usage

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Context-Awareness and Service-Oriented Architecture

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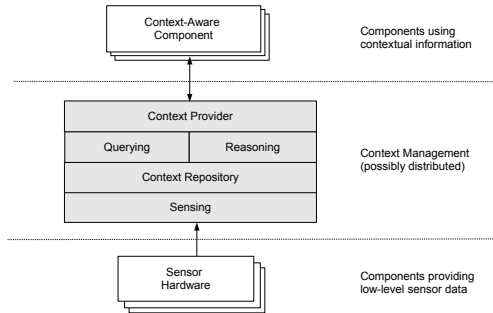 - Context-aware service discovery
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Motivation
Context Management
Selected Systems
Summary

Reference Architecture
Sensing
Context Repository
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General Concepts of Context Management

- Context is managed at different levels of abstraction
- Contextual information
  - Single scalar value, e.g. temperature
  - Vector, e.g. location (latitude, longitude)
  - Abstract situation, e.g. waiting for the bus, lunch break, in a meeting
- Processed by different components/layers according to level of abstraction
- Muliplicity higher layer to lower layer: 1 - *

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A Proposed Layered Reference Architecture

Figure: A proposed layered reference architecture for context management systems

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Sensing

- Sensor hardware provides raw data
- Data tuples represent the state of an observed entity
- Typical examples
  - Temperature
  - Location
  - Movement
  - Proximity of other entities
- Sensing layer
  - Abstracts from underlying hardware
  - Translates between physical and virtual domain

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Context repository

- Stores lower-lever contextual information acquired by sensors
- Data structures according to a formal context-model
- Goal: semantic model that machines can reason about

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Context Models

- Key-value
- Markup-based (hierarchical)
- Logic-based
- Ontology-based

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Ontologies

- In Philosophy: The study of *being* or *existence*
- Concepts
- Attributes
- Interrelationships

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OWL – The Web Ontology Language

- Part of the Semantic Web activity
- Semantic content to be interpreted by machines
- Core elements:
  - Classes
  - Properties
  - Instances
- Identified uniquely by URIs
- Relationships between classes in terms of Boolean operators
- Properties define valid domain, range and cardinality

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OWL – Example

Listing 1: An excerpt of an OWL-descripted food ontology [1]

```
<owl:Class rdf:ID="PotableLiquid">
  <rdfs:subClassOf rdf:resource="#ConsumableThing" />
  <owl:disjointWith rdf:resource="#EdibleThing" />
</owl:Class>

<owl:Class rdf:ID="Juice">
  <rdfs:subClassOf rdf:resource="#PotableLiquid" />
  <rdfs:subClassOf>
    <owl:Restriction>
      <owl:onProperty rdf:resource="#madeFromFruit" />
      <owl:minCardinality
        rdf:datatype="&xsd;nonNegativeInteger">1</owl:minCardinality>
    </owl:Restriction>
  </rdfs:subClassOf>
</owl:Class>
```

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CoOL – ASC model

- Context Ontology-Language [3] defined on top of OWL
- Based on formal context model: ASC
  - Entity
  - Aspect
  - Context Information
  - Scale

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Context Querying and Reasoning

- Querying
  - For the state of another entity (or self)
  - For entities whose contexts satisfy certain criteria
- Reasoning
  - Inferring high-level contextual information from low-level information in repository
  - Existing reasoning engines can be used on ontology-based models
  - Ontologies, repository state, set of rules
- Query languages depend on context data representation

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Context Provider (Aggregation and Delivery)

- Provides contextual information to external client
- Interaction modes
  - Poll (query)
  - Notify (filter)
  - Transparent (trigger)
- Facade that hides intrinsic details of context management
- Potentially composite structure

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Service-Oriented Context-Aware Middleware

- Introduced by Gu, Pung and Zhang [4]
- Concepts from reference architecture realized as independent services
- Open architecture
- Context provider services
- Context interpreter services
    - Context knowledge-base
    - Context reasoner
    - Uses OWL as representation
    - Generalized context ontology and domain-specific ontologies
    - Notify or trigger actions on clients upon satisfaction of FOL statement
- Service location services
    - OWL-like query language

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SOCAM
Service-Oriented Context-Aware Middleware

Figure: Overview of the SOCAM architecture [4]

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CSDS
Context-Sensitive Service Discovery System

- Introduced by Kuck et al. [5, 6]
- Formalized service-discovery model
- Uses concepts from information retrieval
  - Term-based context model
  - Query matched against a collection of services
  - Relevance of service according to ranking function
- User context matched against service context
- Static service context derived from WSDL
- Dynamic context derived from user feedback

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CSDS
Context-Sensitive Service Discovery System

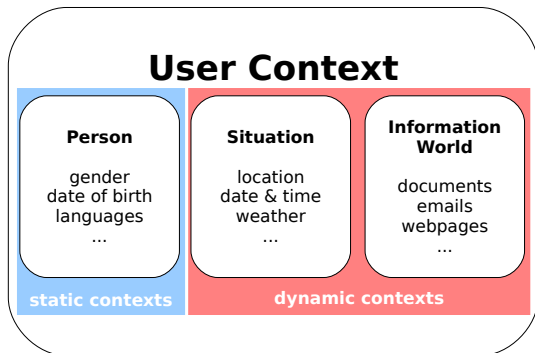Figure: Context of a mobile user [5]

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CSDS
Context-Sensitive Service Discovery System

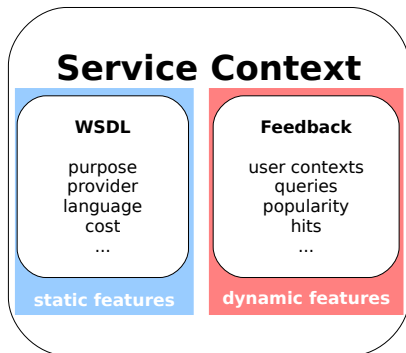Figure: An example service context model [5]

Summary

- Context-Awareness and SOA can mutually take advantage of each other.
- Service-Oriented Architectures help building powerful distributed Context-Management Systems.
- Ontology-based context models help inferring higher-level understanding of situation.

For Further Reading I

W3C:
Food ontology.
Web resource Available online at
`http://www.w3.org/TR/owl-guide/food.rdf`;
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Strang, T., Linnhoff-Popien, C.:
A context modeling survey.
In: Workshop on Advanced Context Modelling, Reasoning and Management as part of UbiComp 2004 - The Sixth International Conference on Ubiquitous Computing, Nottingham, England (September 2004)

For Further Reading II

Strang, T., Linnhoff-Popien, C., Frank, K.:
CoOL: A Context Ontology Language to enable Contextual
Interoperability.
In Stefani, J.B., Dameure, I., Hagimont, D., eds.: LNCS
2893: Proceedings of 4th IFIP WG 6.1 International
Conference on Distributed Applications and Interoperable
Systems (DAIS2003). Volume 2893 of Lecture Notes in
Computer Science (LNCS)., Paris/France, Springer Verlag
(November 2003) 236–247

For Further Reading III

📄 Gu, T., Pung, H.K., Zhang, D.Q.:
A service-oriented middleware for building context-aware services.
J. Netw. Comput. Appl. **28**(1) (2005) 1–18

📄 Kuck, J., Reichartz, F.:
A collaborative and feature-based approach to context-sensitive service discovery.
In: 16th International World Wide Web Conference, Workshop on Emerging Applications for Wireless and Mobile Access (MobEA V), Banff, Alberta, Canada (May 2007)

For Further Reading IV

📄 Kuck, J., Gnasa, M.:
Context-sensitive service discovery meets information
retrieval.
In: Pervasive Computing and Communications Workshops,
2007. PerCom Workshops '07. Fifth Annual IEEE
International Conference on, White Plains, NY, USA (March
2007)

For Further Reading V

📄 Kuck, J., Reichartz, F.:
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